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Ad hoc Meeting on Tungsten
Geneva, 2 July 1992
Item 3 of the provisional agenda

## CONSIDERATION OF PROJECT PROPOSALS BY GOVERNMENTS AND INDUSTRY WHICH COULD BE SUBMITTED FOR POSSIBLE FINANCING UNDER THE SECOND ACCOUNT OF THE COMMON FUND FOR COMMODITIES

### Project proposals received by the UNCTAD secretariat

Note by the secretariat

The revised project proposals have been submitted by China on the basis of comments received from Committee members in accordance with paragraph 36 of the report of the Committee on Tungsten on its twenty-third session (TD/B/C.1/TUNGSTEN/91). The text of the proposals is reproduced as received.

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GE.92-51083

2 April 1992

In accordance with the conclusion in para. 36 of the report of the Committee on Tungsten on its twenty-third session, I hereby submit the revised text of China's three project proposals on tungsten for the consideration of the Ad hoc Meeting on Tungsten.

Tian Ling

Delegate, Permanent Mission of the
People's Republic of China at Geneva.

The UNCTAD Committee on Tungsten hereby submits the following project proposals with its recommendation for financing through the Second Account of the Common Fund.

TITLE OF THE PROJECTS:
(A) Development of the Ultra Fine-grained WC and Cemented Carbide

(B) Development of the Rare Earth Doped Cemented Carbide and Its Mechanism Research

(C) Development of the New Process for Heat-treatment of Cemented Carbide and Its Application

DURATION: Five years

LOCATION: Zhuzhou Cemented Carbide Industry Co., China

NATURE: Development of new grades of cemented carbide so as to increase their performance and reduce production cost, to improve product structure, to strengthen their ability to compete with substitute materials, and to expand the application field of tungsten.

TOTAL COST: SDR 3,357,400 (Basis 1 SDR = USD 1.385)
USD 4,650,000

FINANCING (AS GRANT)
SOUGHT FROM THE FUND: SDR 2,815,884 (USD 3,900,000)

CO-FINANCING SOUGHT
FROM CHINA: SDR 541,516 (USD 750,000)
(Excluding the input of existing Chinese equipment for carrying out the three projects, see ANNEX 2)

Project A: SDR 216,606 (USD 300,000) See Annex-A3
Project B: SDR 129,964 (USD 180,000) See Annex-B3
Project C: SDR 194,946 (USD 270,000) See Annex-C3

PROJECT EXECUTING AGENCY: China National Nonferrous Metals Industry Corp.

ESTIMATED STARTING DATE: 1993

The UNCTAD Committee on Tungsten hereby submits the following project proposal with its recommentation for financing through the Second Account of the Common Fund.

| | | |
|---|---|---|
| TITLE OF THE PROJECT: | (A) | Development of the Ultra Fine-grained WC and Cemented Carbide |
| DURATION: | | Five years |
| LOCATION: | | Zhuzhou Cemented Carbide Industry Co., China |
| NATURE: | | This project is aimed at adjusting the product structure and expanding application field of tungsten. It is beneficial for international tungsten industry to develop new highly tough cemented carbide for use under slow cutting speed. |
| TOTAL COST: | | SDR 1,682,300 (Basis: 1SDR= USD 1.385) (USD 2,330,000) |
| FINANCING (AS GRANT) SOUGHT FROM THE FUND: | | SDR 1,249,100 (USD 1,730,000) |
| CO-FINANCING SOUGHT FROM CHINA: | | SDR 216,606 (USD 300,000) |
| PROJECT EXECUTING AGENCY: | | China National Nonferrous Metals Industry Corp. |
| ESTIMATED STARTING DATE: | | 1993 |

A. Project description:

With the rapid growth of world economy, it is required that the tool materials should have good TRS, high shock resistance and toughness in addition to high hardness. The ultra fine-grained cemented carbide with a combination of the above properties has obtained a wide application in information industry. As the ultra fine-grained cemented carbide cutting tools can be used in either slow or medium cutting speed under heavy load condition, they are excellent tool materials for filling the gap between high speed steel and cemented carbide.

Since 1970s, great efforts have been made in the world to develop ultra fine-grained cemented carbide, there are some achievements in this field. In 1989, Japan promulgated the first standard for ultra fine-grained cemented carbide (JISB 4053-1989). However, the grain size of WC used is 0.3-0.8 micrometer, while the grain size of WC in cemented carbide is 0.6 micrometer. Due to the comparatively large grain size, the combination of toughness and wear resistance is not adequately satisfactory with the maximum TRS of 3000 $N/mm^2$ and average TRS of 2000 $N/mm^2$.

According to results of latest research, the strength and hardness of cemented carbide can be effectively and harmoniously combined without an increase in hardness at the expense of the other or vice versa, provided that the average grain size of WC in cemented carbide is less than 0.3 micrometer.

Up to now, there is few ultra fine-grained cemented carbide developed with grain size less than 0.3 micrometer in the world. It is known that the preparation of less than 0.3 micrometer particle size of WC and Co powder is a prerequisite for producing 0.3 micrometer grain-sized cemented carbide.

Main components of the project:

(i) Objectives:

The overall objective of this project is to adjust product structure, and develop ultra fine-grained cemented carbides.

(ii) The strategy and target beneficiaries:

The main strategy is to expand the use of cemented carbide in special machining and electronics industry, such as tools for cutting high temperature alloys and mini-drill for printed circuit board. The technology of the project can be transferred gratis to member countries of Committee on Tungsten, or under arrangement by the Committee to provide technical assistance to those interested member countries.

(iii) Expected situation at the completion of the project:

Ultra fine-grained cemented carbide with average WC grain size < 0.3 micrometer will be developed at the end of the project.

(iv) The implementation arrangement:

During the next month following the approval of the project, the Ministry of Foreign Economic Relations and Trade of China and China National Non-ferrous Metals Industry Corp. together with Zhuzhou Cemented Carbide Industry Co. shall meet to finalize the task, objective and executive plan.

When the task is determined and finalized, the departments and personnel concerned shall, within 6 months, complete organization, practical plan, and literature survey; determine process route; conduct overseas technical exchange.

Detailed schedule and executive plan for 1993-1994 are listed in the attachment; objective plan for 1995-1997 shall be worked out in the fourth quarter of the second year after the project is started.

B. Project justification

(a) Economic & financial asepcts:

The execution of this project can bring the production of world ultra fine grained cemented carbide up to a higher level with new series of grades. It is predicted that economic return of this project can be increased by 20-30% in China.

(b) Technical appraisal and feasibility:

It is known that the ultra fine-grained cemented carbide with a good combination of TRS, shock resistance and toughness as well as hardness is an excellent tool material, and is gaining increasing use in special machining industry.

At present, the WC grain size in the ultra fine-grained cemented carbide ranges between 0.4-0.7 micrometer. Efforts have been made in China years ago, and some achievements have been obtained. Now China can produce WC powder with average particle size of 0.5 micrometer, and cemented carbide with WC grain size of 0.7-0.8 micrometer. Satisfactory results have been obtained for use in machining heat-resistant alloys.

In the development of this project, research can also be made in preparing active ultra WC based catalyst for application in petrochemical industry.

(c) Environmental aspects:

The ultra fine powder for this project, due to the protection measures, shall not lead to dust pollution of the environment.

(d) Social & economic aspects:

Research and development at the end-use level appears to be price-sensitive. It seems to have accelerated the substitution of other materials for tungsten during periods of rising prices, such as during the late 1970s and the beginning of the 1980s. The situation has since been reversed with the recent decline of tungsten price. However, despite low price, tungsten appears to be slow to recover the ground lost to the other materials. One reason for explaining the difficulty of tungsten to recover the lost ground is the relative neglect of linking basic R&D to develop new grades of tungsten materials and the applied R&D pursued for their application in industry at the end-user level. The development of the ultra fine-grained cemented carbide shall facilitate the world cemented carbide industry to open new wider field of application to make up for the lost ground.

(e) Relevance to the Common Fund's objectives, priorities and policy guidelines. This project shall contribute to the expansion of tungsten, the strengthening of its competitiveness with substitute materials.

C. Objectives:

1.1. Objective 1

Development of colloidal tungsten compound and ultra fine WC, and research on passivation of ultra fine WC and its storing measures.

1.1. Output 1
Development of WC powder with average particle size < 0.3 micrometer.

1.1.1. Activity 1
The competent authorities and Zhuzhou Cemented Carbide Industry Co. shall evaluate the production process and the technological route of the ultra fine-grained cemented carbide, and reach an agreement.

1.1.2. Activity 2

A detailed literature survey and extensive technical exchange shall be conducted so as to work out a rational research plan after analysis and evaluation, covering the development of ultra fine WC powder and its cemented carbide, promotion and application as well as the assessment of the achievements.

1.1.3. Activity 3

Establishment and perfection of the laboratorial equipment, capable of doing pilot experiment.

1.1.4. Activity 4

The raw material for the production of ultra fine WC shall be prepared by selection of either chemical precipition, colloidal chemistry, addition of activating agent, or organic compound of metal tungsten.

1.1.5. Activity 5

The process parameters for the obtaining of ultra fine WC shall be optimized through selection of way of carburization and equipment.

1.1.6. Activity 6

Research on the passivation of ultra fine powder and its storing measures.

1.2 Output 2

Development of WC powder with average particle size < 0.2 micrometer.

1.2.1. Activity 1

Establishment of plasma laboratory through equipment purchase, installation and running-in.

1.2.2. Activity 2

Research on the process parameters for producing ultra fine WC powder by plasma furnace.

1.2.3. Activity 3

Development of ultra fine WC by means of DC plasma.

1.2.4. Activity 4

Research on passivation technique for stabilizing ultra fine WC powder.

1.2.5. Activity 5

Research on special protection technique for storing ultra fine powder.

1.2.6. Activity 6

Research on preparation process of tungsten compound.

2. Objective 2

Development of ultra fine-grained cemented carbide.

2.1. Output 1

Development of ultra fine-grained cemented carbide with average grain size < 0.5 micrometer, HRA 91.5 and TRS -3000 $N/mm^2$.

2.1.1. Activity 1
Selection of preparing process and equipment for the production of mixed ultra fine powders.

2.1.2. Activity 2
Compaction of mixed ultra fine powders, and selection of compaction method and its equipment.

2.2. Output 2
Development of ultra fine-grained cemented carbide with average grain size < 0.3 micrometer, HRA 92.5 and TRS - 3500 $N/mm^2$.

2.2.1. Activity 1
Optimization of the process parameters for quick vacuum sintering under low temperature.

2.2.2. Activity 2
Selection of grain growth inhibitor.

3. Objective 3
Expansion of the use of WC powder in the refining of petroleum.

3.1. Output 1
Preparation of active ultra fine WC powder.

3.1.1. Activity 1
Survey of literature, formulation of production process.

3.1.2. Activity 2
Purchase of equipment and raw materials.

3.1.3. Activity 3
Execution of the preparation process so as to produce the raw material for active ultra fine WC.

3.1.4. Activity 4
Production of active ultra fine WC via tungsten raw material.

3.1.5. Activity 5
Testing of the property of active ultra fine WC powder.

3.2. Output 2
Application of WC based catalyst in hydrogen-added refining or fragmentation of secondary fraction oil.

3.2.1. Activity 1
Designing of the composition of hydrogen-added WC based catalyst.

3.2.2. Activity 2
Trial-production of hydrogen-added WC based catalyst.

3.2.3. Activity 3
Testing of the activity of the catalyst composition by chromatographic micro-reaction tester.

3.2.4. Activity 4
Determination of the catalystic property of hydrogen-added refining or fragmentation in simulation industrial production.

3.2.5. Activity 5
Determination of the optimum composition of the catalyst.

3.3. Output 3
Testing method and specification for the catalystic property of the WC.

3.3.1. Activity 1
Establishment of the equipment and instrument for testing catalystic property.

3.3.2. Activity 2
Establishment of method and specification for determining the catalystic property of WC.

3.3.3. Activity 3
Testing of the WC based catalystic property.

D. Input
The inputs required to carry out the project's activities as well as to obtain the specific outputs are given in Annex-A1.

E. Risk
As the price of cobalt is on the rise recently, it is expected that it may have certain effect on this project. However, in that event, China will put in additional investment to make it up.

F. The project budget
This project is a rather difficult one from the point of technology, as it covers the development of equipment, research on analysis and testing as well as production process and basic theory, so amount of SDR 1,249,100 (USD 1,730,000) is required to be financed by the Common Fund (see Annex -A2). Additionally, China will invest SDR 216,606 (USD 300,000) to help complete project A (see Annex -A3).

G. Provisional work plan:
See Annex-A4.

H. Project management
Project Executing Agency: China National Nonferrous Metals Industry Corp.

The sponsoring ICB is willing and able to assume responsibility as a Supervisory Body for the project without charge:

YES _____ No _____

If not, give alternative proposal:

I. Project monitoring, reporting and evaluation:
This project will be periodically monitored by Committee on Tungsten as per its policies and procedures. The result of the project work will be

evaluated annually as per the Committee's evaluation system. Progress report will be prepared at six-monthly intervals, and there will be a final report on the conclusion of the project.

J. Annexes:

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| Annex 1 | Statistics for the export of tungsten concentrate by China between 1987-1991 |
| Annex 2 | Inputs by China |
| Annex-A1 | Inputs by Common Fund |
| Annex-A2 | Budget for financing by Common Fund |
| Annex-A3 | Budget for investment by China |
| Annex-A4 | Provisional work plan |

| ON BAHALF OF | NAME/TITLE | SIGNATURE | DATE |
|---|---|---|---|
| ( THE ICB ) | ..... | ..... | ..... |

The UNCTAD Committee on Tungsten hereby submits the following project proposal with its recommendation for financing through the Second Account of the Common Fund.

| | | |
|---|---|---|
| TITLE OF THE PROJECT: | (B) | Development of the Rare Earth Doped Cemented Carbide and Its Mechanism Research |
| DURATION: | | Four years |
| LOCATION: | | Zhuzhou Cemented Carbide Industry Co., China |
| NATURE: | | This project is intended to improve practical properties, and to enhance its ability to compete with substitute materials. It's beneficial to make full use of tungsten resources. |
| TOTAL COST: | | SDR 909,750 (Basis 1 SDR = USD 1.385)<br>(USD 1,260,000) |
| FINANCING (AS GRANT) SOUGHT FROM THE FUND: | | SDR 606,500 (USD 840,000) |
| CO-FINANCING SOUGHT FROM CHINA: | | SDR 129,964 (USD 180,000) |
| PROJECT EXECUTING AGENCY: | | China National Nonferrous Metals Industry Corp. |
| ESTIMATED STARTING DATE: | | 1993 |

A. Project description:

As the WC based cemented carbide is a kind of comparatively expensive material, its scope of application is limited to some extent. The rapid growth of world's economy shall lead to an increase in demand for cemented carbide and development of new application. Therefore it is necessary to look for a way of having a material with better property than the existing traditional cemented carbide while at same time without giving up the potential market of tungsten. The development or rare earth doped cemented carbide can achieve that purpose.

The cemented carbide, when doped with rare earth, will show an increase of TRS by 10-20%, and hardness by 0.5-1 HRA. What's more, it has low porosity and higher wear resistance. So there is important significance in bringing the performance of cemented carbide to full play, in reducing production cost and opening new field of application.

Research on the use of rare earth in cemented carbide was started in early 1960s, and was limited to laboratory rather than mechanism at that time in the world. So far, there is no rare earth doped cemented carbide to the market.

Some achievements have been obtained in China with regard to the use of rare earth in cemented carbide, there are a few grades of such products put into production. In terms of mechanism, it is found out that addition of rear earth element to cemented carbide can improve the physical properties of binding phase and performance of cemented carbide as a whole. It can be predicted that the doping of rear earth shall significantly enhance the

service life of cemented carbide. Further research into the effect of rare earth addition on wettability of hard phase and re-enforcing mechanism of binding phase shall be of help in promoting this project to a higher level.

Main components of the project:

(i) Objectives:
The overall objective of this project is to fully utilize tungsten resources, to improve the properties of existing grades with doping of rare earth, and to increase its ability to compete with substitute materials.

(ii) The strategy and target beneficiaries:
The target is to develop rare earth doped cemented carbide for wider use, such as hot working tools or dies, structural parts and wear resistant part under hot environment in addition to its use as cutting inserts. The technology for the production of new rare earth doped cemented carbide can be transferred gratis to member countries of Committee on Tungsten, or under arrangement by the Committee to provide technical assistance to those interested member countries.

(iii) Expected situation at the completion of the project:
On the basis of a slight increase in hardness, the durability of rare earth doped cemented carbide can be doubled with an increase in TRS by 10-20%.

(iv) The implementation arrangement:
The competent authorities and Zhuzhou Cemented Carbide Industry Co. undertaking this project shall evaluate the production process of the development of rare earth doped cemented carbide.

At least there shall be 3 personnel who have a good understanding of the progress plan and research direction of this project. In addition, they should be able to conduct technical exchange activities at home and abroad.

Presenting stage research reports on the proper kind of rare earth additives, its doping method and amount.

B. Project justification

(a) Economical and financial aspects:
As this project is cost effective, and it can enhance the comprehensive properties of the existing cemented carbide grades. It is expected that a additional income of USD 7,200 can be gained for one ton of cemented carbide doped with rare earth.

(b) Technical appraisal and feasibility:
The research on doping cemented carbide with certain rare earth was initiated in the world as early as 1960s. According to some literature report, addition of a small amount of cerium or mixed rare earth to the binding phase can result in improving the high temperature and anti-oxidation properties as well as toughness.

Late in 1980s China has made some progress in the research on application of rare earth in cemented carbide. It was discovered that the rare earth doped cemented carbide had shown some improvement in

TRS, high temperature property and durability. When it was put into trial use as cleaning scraper for rubber conveyer, the tool life was significantly improved. So far China has trial-produced, on a small basis, rare earth doped cemented carbide for domestic use with comparatively good results.

Meanwhile, preliminary research has been made on the microstructure of so doped cemented carbides, and basic theory for the mechanism of strengthening cemented carbide by doping rare earth. It shows that the rare earth can improve the structure of Co binding phase and physical & mechanical property, which eventually leads to an increase in the property and durability of cemented carbide.

(c) There is no detrimental effect to the environment.

(d) Social and economic aspects:
Although the research on doping cemented carbide with rare earth was initiated in 1960s, there is no commercial product in the market yet, this seems to have something to do with the uncertainty of product quality and the re-enforcing mechanism of cemented carbide as well as process control. The implementation of the project shall help make progress in this field so as to benefit all cemented carbide producers.

(e) Relevance to the Common Fund's objectives, priorities and policy guidelines. This project is to increase the performance of cemented carbide, to strengthen its competitiveness with substitute materials, and to reduce production cost.

C. Objectives:

The overall objective of this project is to adjust product structure, and to develop rare earth doped cemented carbide so as to improve the property of the existing grades to increase its ability to compete with substitute materials.

1.1. Output 1
On the basis of a slight increase in hardness, the durability of rare earth doped cemented carbide can be doubled with an increase in TRS by 10-20%.

1.1.1. Activity 1
Research on the proper kind of rare earth additive, its doping method and amount.

1.1.2. Activity 2
Research on the microstructure and wettability of rare earth doped cemented carbide.

1.1.3. Activity 3
To determine process parameters for pilot experiment, and complete designing of rare earth doped cemented carbide grades.

1.2. Output 2
To present a report on development and its mechanism research.

1.2.1. Activity 1
Further research on the re-enforcement mechanism of doping rare earth by utilizing various testing means.

1.3. Output 3
Development of the analytical and testing method for determing rare earth element.

1.3.1. Activity 1
Research on the chemical analysis of rare earth element content.

1.3.2. Activity 2
Research on the form of presence, morphology and structural characteristics of rare earth in cemented carbide by means of X-ray diffraction, TEM and AEM etc.

2. Objective 2
Promotion and application of the rare earth doped cemented carbide.

2.1. Output 1
The increase in tool life of rare earth doped cemented carbide can reduce tool wear, tool exchange time, tool cost; enhance machining efficiency and quality, thus leading to a decrease in machining cost.

2.1.1. Activity 1
Promotion and application of rare earth doped cemented carbide in machining industry in China.

2.2. Output 2
The production technology of the new rare earth doped cemented carbide can be transferred gratis to member countries of Committee on Tungsten for mutual benefit.

D. Input
The inputs required to carry out the project's activities as well as to obtain the specific outputs are given in Annex B1.

E. Risk
No risk.

F. The project budget
This project requires financing of SDR 606,500 (USD 840,000) from the Common Fund, see Annex B2. Additionally, China will invest SDR 129,964 (USD 180,000), see Annex B3.

G. Provisional work plan
See Annex B4.

H. Project management
Project Executing Agency: China National Nonferrous Metals Industry Corp.

The sponsoring ICB is willing and able to assume responsibility as a Supervisory Body for the project without charge:

YES _____ NO _____

If not, give alternative proposal:

I. Project monitoring, reporting and evaluation:

This project will be periodically monitored by the Committee on Tungsten as per its policies and procedure. The result of the project work will be evaluated as per the Committee's evaluation system. Progress reports will be prepared at six-monthly intervals, and there will be a final report on the conclusion of the project.

J. Annexes:

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|---|---|
| Annex 1 | Statistics for the export of tungsten concentrate by China between 1987-1991 |
| ANNEX 2 | Inputs by China |
| ANNEX-B1 | Inputs by Common Fund |
| ANNEX-B2 | Budget for financing by Common Fund |
| ANNEX-B3 | Budget for investment by China |
| ANNEX-B4 | Provisional work plan |

| ON BEHALF OF | NAME/TITLE | SIGNATURE | DATE |
|---|---|---|---|
| ( THE ICB ) | ..... | ..... | ..... |

The UNCTAD Committee on Tungsten hereby submits the following project proposal with its recommendation for financing through the Second Account of the Common Fund.

| | | |
|---|---|---|
| TITLE OF THE PROJECT: | (C) | Development of the New Process for Heat-treatment of Cemented Carbide and Its Application |
| DURATION: | | Four years |
| LOCATION: | | Zhuzhou Cemented Carbide Industry Co., China |
| NATURE: | | This project is intended to improve the performance of cemented carbide, which is beneficial for the tungsten consuming countries to increase working efficiency and reduce processing cost. |
| TOTAL COST: | | SDR 1,350,180 (Basis 1 SDR = USD 1.385) (USD 1,870,000) |
| FINANCING (AS GRANT) SOUGHT FROM THE FUND: | | SDR 960,290 (USD 1,330,000) |
| CO-FINANCING SOUGHT FROM CHINA: | | SDR 194,946 (USD 270,000) |
| PROJECT EXECUTING AGENCY: | | China National Nonferrous Metals Industry Corp. |
| ESTIMATED STARTING DATE: | | 1993 |

A. Project description

The final main use of tungsten is to produce cemented carbide. During its practical application of inserts and tips, there usually occurs early chipping or wear, because its toughness and wear resistance can not be well combined. For many years, every effort has been made to have a high performance cemented carbide with a good combination of wear resistance and toughness. Heat-treatment of cemented carbide is a simple and efficient way. It is found out that change in the composition of binding phase and structure by heat-treatment can increase toughness. In this sense, there is important practical significance in revealing the re-enforcing mechanism of cemented carbide by heat-treatment, investigating the optimum condition of heat-treatment, in developing new series of heat-treated cemented carbide with well combined properties, in widening its application scope, and in enhancing its ability to compete with other substitution materials.

The possibility of heat-treatment of cemented carbide was presented as early as in the 1940s. Such research was conducted in former Soviet Union, Sweden in the 1960s. In mid-1980s, China began to research on heat-treatment of WC-Co alloy for mining tools. It is shown by practical use that the occurrence of chipping is obviously reduced with an increase in drilling efficiency and a decrease in drill and mining cost. However, further effort is still required to research on the heat-treatment of cutting inserts, drawing and forming dies, and wear resistant parts.

Main components of the project:

(i) Objectives:
The overall objective of this project is to improve the cemented carbide performance as a whole, to expand its application, and to fully utilize the tungsten resources.

(ii) The strategy and target beneficiaries:
The main target is to develop series of new heat-treated cemented carbide with better performance so as to expand its application field. Research achievements can be transferred gratis to member countries of Committee on Tungsten, or under arrangement by the Committee to sponsor workshop or seminar in China or overseas for those interested member countries.

(iii) Expected situation at the completion of the project:
As a result, failure rate of the heat-treated non-brazed tools can be decreased by 50% with double service life.

(iv) Implementation arrangement:
During the next month following the approval of this project, the Ministry of Foreign Economic Relations and Trade and China National Non-ferrous Metals Industry Corp. together with Zhuzhou Cemented Carbide Industry Co. and personnel concerned shall meet to finalize the task, objective and workplan.

Upon definition of the task, Zhuzhou Cemented Carbide Industry Co. shall, within 3 months, complete organization and work out practical plan, optimize literature survey, determine process route, and conduct overseas technical exchange.

Detailed workplan and schedule are listed in the attachment. The objective plan for 1995-1996 shall be made in the fourth quarter of the second year after this project is started, meanwhile a stage summary report will be presented.

B. Project justification:

(a) Economical and financial aspects:
Series of new heat-treated cemented carbide grades shall be developed with double service life. Judging from the Chinese market, an annual additional income of USD 1,000,000- 2,000,000 will be gained when the new grades are put into production.

With the improvement in the product property and durability, the user's tool cost shall be decreased, and working efficiency is increased, thus providing more choices for user's selection, bringing about an increase in both economic and social benefit for the user.

(b) Technical appraisal and feasibility:
The possibility for heat-treatment of cemented carbide was presented as early as 1940s. In recent years, many researchers have paid much attention to this subject. Investigation and experiments have been done in former Soviet Union, Sweden, Germany, South Africa and China etc. Especially in the former Soviet Union, great efforts were made systematically with establishment of heat-treatment process for a

number of cemented carbide grades, and it was successfully applied into production. The heat-treated mining tool, punching die, heading die, anvil and other tools for use under shock load condition can exhibit better quality.

Researchers in Sweden, Germany and China gained a better understanding of phase transformation of Co phase by further investigation into the re-enforcement mechanism of heat-treating cemented carbide. All this previous work has shown practically and theoretically that there is a bright prospect and great potential for heat-treating cemented carbide. Our preliminary research indicated that the heat-treatment of cemented carbide can change the composition and structure of binding phase, leading to a significant improvement in the physical & mechanical properties (toughness in particular), to the end of increasing tool life.

(c) Environmental aspects:
There is no detrimental effect to the environment.

(d) Social and economic aspects:
This project shall contribute to the expansion of cemented carbide by improving its properties in all of the cemented carbide producers, and it is beneficial especially for the developing countries to improve the structural conditions in market enhancing the long-term competitiveness.

(e) Relevance to the Common Fund's objective, priorities and policy guidelines. This project is to improve the product quality, enhancing working efficiency, and to expand its application field.

C. Objectives:

Objective 1
Research on the heat-treatment condition for the > 8% Co cemented carbide; on the mechanism of Co phase re-enforcement and toughness of cemented carbide.

1.1. Output 1
The TRS of heat-treated WC-Co and WC-TiC-TaC-Co(>8%) alloys shall be increased by 10%-30% with double durability.

1.1.1. Activity 1
Upon approval of the project, Zhuzhou Cemented Carbide Industry Co. shall immediately finalize the task, work out detailed objectives and execution plan.

1.1.2. Activity 2
To conduct extensive literature survey, determine process route and conduct overseas technical exchange.

1.1.3. Activity 3
The four-year R & D workplan shall be drawn out, covering the development of heat-treated cemented carbide, promotion and application and achievement evaluation.

1.1.4. Activity 4
Establishment of a vacuum sintering heat-treatment pilot laboratory via the purchase of furnace, installation and running-in.

1.1.5. Activity 5
Research on the relation between the change in property and structure under different heat-treating conditions.

1.1.6. Activity 6
Research on different quenching methods and their effect.

1.1.7. Activity 7
Research on the critical quenching and cooling speed for the heat-treatment of cemented carbide with different composition and structure.

1.2. Output 2
With the improvement in product properties, the heat-treated cemented carbides can be substituted for some cemented carbides with special properties, providing a wider range of choice for the user.

The increase in durability can reduce tool cost for the user, increase working efficiency, resulting in more economic return for the user.

1.2.1. Activity 1
Optimization of the process parameters for heat-treatment of WC-Co systems.

1.2.2. Activity 2
Research on the microstructure of heat-treated WC-Co systems.

1.2.3. Activity 3
On-site performance test for heat-treated WC-Co systems.

1.2.4. Activity 4
Research on the heat-treatment process for WC-TiC-(NbC.TaC)-Co systems.

2. Objective 2
Research on the heat-treatment condition of < 8% Co cemented carbide; on the possibility of toughening low Co-containing cemented carbide and achievable degree of commercializing the heat-treated low Co-containing cemented carbides.

2.1. Output 1
To determine the possibility of commercializing the heat-treated < 8% Co-containing cemented carbides, and present an evaluation report.

2.1.1. Activity 1
Research on process parameters for heat-treatment.

2.1.2. Activity 2
On-site comparative test for heat-treated cemented carbide.

2.1.3. Activity 3
Research on the mechanism of heat-treatment process.

3. Objective 3

Research on the failure characteristics of heat-treated cemented carbide tools in practical use in order to determine the limit of condition in application.

3.1. Output 1

Failure rate of the heat-treated non-brazed cemented carbide tools can be decreased by 50% with double service life.

3.1.1. Activity 1

Research on the influence of various brazing method and brazing condition that are detrimental to the heat-treatment effect.

3.1.2. Activity 2

Extensive on-site comparative test.

3.1.3. Activity 3

Research on the failure characteristics and fracture mechanism of the heat-treated cemented carbides by means of TEM and AEM etc.

D. Input

The inputs required to carry out the project's activities as well as to obtain the specific outputs are given in Annex-C1.

E. Risk

No risk.

F. The project budget

This project requires financing of SDR 960,290 (USD 1,330,000), see Annex-C2. Additionally, China will invest SDR 194,946 (USD 270,000) to help complete the project, see Annex-C3.

G. Provisional work plan: (1993-1994)

See Annex-C4.

H. Project management

Project Executing Agency: China National Nonferrous Metals Industry Corp.

The sponsoring ICB is willing and able to assume responsibility as a Supervisory Body for the project without charge:

YES _____ NO _____

If not, give alternative proposal:

I. Project monitoring, reporting and evaluation:

This project will be periodically monitored by the Committee on Tungsten as per its policies and procedures. The result of the project will be evaluated annually as per the Committee's evaluation system. Progress reports will be prepared at six-monthly intervals, there will be a final report on the conclusion of the project.

J. Annexes:

Annex 1 Statistics for the export of tungsten concentrate by China between 1987-1991

ANNEX 2 Input by China

ANNEX C1 Inputs by the Common Fund

ANNEX C2 Budget for financing by Common Fund

ANNEX C3 Budget for investment by China

ANNEX C4 Provisional Work plan

| ON BEHALF OF | NAME/TITLE | SIGNATURE | DATE |
|---|---|---|---|
| (THE ICB) | ..... | ..... | ..... |

ANNEX 1

In addition to improving the product quality, increasing working efficiency, reducing production cost and fully utilizing tungsten resources, the implementation of the three projects is also envisaged to rationally adjust the world tungsten market structure, to suitably control the amount of export of tungsten ore concentrate so as to bring more benefit to the tungsten producing countries. The following table will show the efforts made by China to reduce the export of tungsten concentrate from 11905 tons in 1987 to 3217 tons in 1991. The suspension of tungsten ore concentrate quotation by China for one year beginning from Jan. 1, 1991 helped bring the low tungsten concentrate price from around USD 44/MTU up to around USD 63/MTU, which was widely appreciated by many tungsten producing countries.

Export of Tungsten Ore Concentrate by China Between 1987-1991 (Ton W Content)

| Year | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|
| Quantity | 11905 | 14054 | 15914 | 8472 | 3127 |

ANNEX 2

Inputs by China

A. List of existing equipment and laboratory instruments at Zhuzhou Cemented Carbide Industry Co. for carrying out the three projects' activities.

| | | | |
|---|---|---|---|
| 1 | Small hydrogen reduction furnace, automatic push type | 1 | |
| 2 | Small carburizing furnance, 80mm in diameter | 1 | |
| 3 | Cylinder for ball mill, 8x4L | 10 | |
| 4 | V-type mixer, 50L | 1 | |
| 5 | High efficiency V-type mixer, 30L | 1 | |
| 6 | Vibration ball mill, 100L | 1 | |
| 7 | Wet ball mill, 30L | 1 | |
| 8 | Planetary vacuum drying mixer, 100L | 1 | |
| 9 | Spray dryer, 10KG/h | 1 | |
| 10 | Dorst automatic press, 15t | 1 | |
| 11 | Single-shaft hydraulic press, 25t, 40t, 60t | 1 | each |
| 12 | Frame type press, 1000t | 1 | |
| 13 | Hydraulic press with horizontal pressing, 100t | 1 | |
| 14 | Push type sintering furnace (Mo wire) | 1 | |
| 15 | GCA vacuum sintering furnace, 400x400x1000 | 1 | |
| 16 | Hot press, 50t | 1 | |
| 17 | Vaccum heat-treating furnace, 50KW, 1350°C | 1 | |
| 18 | Vaccum tempering and annealing furnace, 30KW, 800°C | 1 | |
| 19 | CVD and PVD coating furnace | 1 | each |
| 20 | Powder injection machine (200g) | 1 | |
| 21 | Pressure injection machine (50g) | 1 | |
| 22 | CIP, 1200 mpa | 1 | |
| 23 | HIP | 1 | |
| 24 | Extrusion press, 200t | 1 | |
| 25 | Spectophotometer, UV-260 (Japan) | 1 | |
| 26 | Atomic adsorption spectophotometer, AA-670 (Japan) | 1 | |
| 27 | Oscillograph polarograph | | |
| 28 | High carbon analylizer | 1 | |
| 29 | Pulse coulomb oxygen analylizer | 1 | |
| 30 | Pulse heating chromatograph | 1 | |
| 31 | Sulphur analyllzer, SA 2002L (Germany) | 1 | |
| 32 | Nitrogen and oxygen analylizer, NOA 2003 (Germany) | 1 | |
| 33 | Carbon analylizer, CA 200H (Germany) | 1 | |
| 34 | Grating spectrograph, PGS-2 (Germany) | 1 | |
| 35 | Direct-read optical spectrometer (imported) | 1 | |
| 36 | DC plasma spectrometer, S-SV (USA) | 1 | |
| 37 | Metallograph, NEOPHOT21 (Germany) | 1 | |
| 38 | X-ray fluorescent/diffratometer PW140 41700 | 1 | |
| 39 | Electronic microscope, JEM-2000EX (Japan) | 1 | |
| 40 | Electronic scanning microscope, ASM-SX (Japan) | 1 | |
| 41 | Image analylizer QTM-720 (UK) | 1 | |
| 42 | Universal material testing, AG-10 TA (Japan) | 1 | |
| 43 | Fatigue tester, PWS-200 | 1 | |
| 44 | Elastic modulus tester | 1 | |
| 45 | High temperature strength tester | 1 | |
| 46 | High temperature hardness tester | 1 | |

| | | |
|---|---|---|
| 47 | Small energy multi-shock tester | 1 |
| 48 | Wear tester, M-200 | 1 |
| 49 | FSSS analylizer | 1 |
| 50 | BET analylizer | 1 |
| 51 | Particle size distribution analylizer | 1 |
| 52 | Particle nephometer | 1 |
| 53 | Coercive force meter | 1 |
| 54 | Magnetic satuation tester | 1 |
| 55 | Specific resistance meter | 1 |
| 56 | High frequency welding machine | 1 |
| 57 | Insert grinder | 1 |
| 58 | Internal grinder | 1 |
| 59 | External grinder | 1 |
| 60 | Tool grinder | 1 |
| 61 | Perimeter grinder | 1 |
| 62 | Plane grinder | 1 |
| 63 | Chamfer grinder | 1 |
| 64 | Dumpling machine | 1 |

Value of the existing equipment after depreciation: USD 4,180,000

| | | |
|---|---|---|
| B. | Raw material | |
| | WC | 28t |
| | Co | 2.8t |
| | TaC | 0.1t |
| | Rare earth | 0.1t |
| C. | Personnel | 22 |

ANNEX-A1

A. Inputs by Common Fund

| | Description | Quantity | Source |
|---|---|---|---|
| 1. | Equipment | | |
| 1.1 | Low pressure HIP/vacuum sintering furnace | 1 | Common Fund |
| 1.2 | Energy dispersive (small angle) X-ray analyzer | 1 | Common Fund |
| 1.3 | 50 KW DC plasma furnace | 1 | Common Fund |
| 1.4 | Chromatographic micro-reaction tester | 1 | Common Fund |
| 1.5 | reaction spray equipment | 1 | Common Fund |

B. Inputs by China, see Annex 2 for project A, B and C.

ANNEX-A2

1. Budget for input by the Second Account of the Common Fund

| | Description | Special drawing right | |
|---|---|---|---|
| 1.1 | Equipment | | |
| | Low pressure HIP/vacuum sintering furnacee | SDR | 505,420 |
| | Energy dispersive (small angle) X-ray analyzer | SDR | 108,300 |
| | 50 KW DC plasma furnace | SDR | 202,170 |
| | Chromotographic micro-reaction tester | SDR | 144,400 |
| | Reaction spray equipment (RSE) | SDR | 72,200 |
| | Subtotal: | | 1,032,490 |
| 1.2 | Reagent, material (key materials and special reagent for structure testing and process research) | SDR | 57,760 |
| 1.3 | Mission cost (project formulation, monitoring and evaluation) | SDR | 46,940 |
| 1.4 | Duty travel (literature survey, selection of equipment etc.) | SDR | 32,490 |
| 1.5 | Miscellaneous (communications etc.) | SDR | 21,660 |
| 1.6 | Contingency | SDR | 57,760 |
| | Total | SDR | 1,249,100 |

2. Project budget for the financing under the Second Account (unit: SDR)

| | Total | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|
| Equipment | 1,032,490 | 108,300 | 866,425 | 57,765 | - | - |
| Reagent, material | 57,760 | 7,220 | 14,440 | 21,660 | 7,220 | 7,220 |
| Mission cost | 46,940 | 21,660 | 7,220 | 7,220 | | 10,840 |
| Duty travel | 32,490 | 10,830 | 14,440 | | 7,220 | |
| Miscellaneous | 21,660 | 7,220 | 3,610 | 3,610 | 3,610 | 3,610 |
| Unpredictables | 57,760 | | | 14,440 | 21,660 | 21,660 |
| Total | 1,249,100 | 155,230 | 906,135 | 104,695 | 39,710 | 43,330 |

ANNEX-A3

Budget for investment by China for Development of Ultra fine-grained WC and Cemented Carbide.

Total: Special drawing rights 216,606 (USD 300,000)

Budget Unit: SDR

| | Total | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|
| Testing etc. | 43,320 | 8,600 | 8,650 | 8,700 | 8,680 | 8,690 |
| Contracts & service | 21,660 | 5,420 | 4,830 | 6,000 | 5,410 | ---- |
| Administration | 10,830 | 2,380 | 2,060 | 2,120 | 2,180 | 2,090 |
| Raw materials | 57,760 | 12,500 | 12,120 | 11,830 | 10,900 | 10,410 |
| Power & salary | 64,980 | 12,840 | 12,910 | 12,970 | 13,030 | 13,230 |
| Duty travel & survey | 18,056 | 6,506 | 5,000 | 4,080 | 2,470 | ----- |
| Total | 216,606 | 48,246 | 45,570 | 45,700 | 42,670 | 34,420 |

ANNEX-A4

Provisional Work plan
(first and second year of the five-year project)

| | Content | 1993 | | | | | | | | | | | | 1994 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1. | Preparation of ultra fine WC powder | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.1 | Selection of raw material | - | - | - | - | - | - | - | - | - | - | - | - | | | | | | | | | | | | |
| 1.2 | Setting up plasma Lab | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1.3 | Preparation of ultra fine powder by plasma | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| 2. | Passivation and storing technique for ultra fine powder | | | | | | | | | | | | | | | | | | | | | | | | |
| | selection of equipment | | | | - | - | - | - | - | - | - | - | - | | | | | | | | | | | | |
| 3.2 | Compaction method, selection of equipment | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 3.3 | Optimizing sintering process | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4. | analytical and testing | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.1 | Determination of grain size | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4.2 | Research on grain size | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

ANNEX-B1

A. Inputs by the Common Fund

| Description | Quantity | Source |
|---|---|---|
| 1. Equipment | | |
| 1.1 50 KW vacuum sintering furnace | 1 | Common Fund |
| 1.2 Small vacuum carburizing furnace | 1 | Common Fund |
| 1.3 Vacuum induction smelting furnace | 1 | Common Fund |
| 1.4 Wettability analyzer (computer controlled) | 1 | Common Fund |
| 1.5 Energy spectrometer | 1 | Common Fund |
| 1.6 Wire cutting machine | 1 | Common Fund |

B. Inputs by China
See Annex 2 for project A,B and C.

ANNEX-B2

1. Financing under the Second Account of the Common Fund

1.1 Equipment

| | | |
|---|---|---|
| 50 KW vacuum sintering furnace | SDR | 64,980 |
| Small vacuum carburizing furnace | SDR | 50,540 |
| Vaccum induction smelting furnace | SDR | 54,150 |
| Wettability analyzer (computer-controlled) | SDR | 36,100 |
| Energy spectrometer | SDR | 144,400 |
| Wire cutting machine | SDR | 180,510 |
| Subtotal: | SDR | 530,680 |
| 1.2 Reagent, material (special reagent for testing, and accessories) | SDR | 14,450 |
| 1.3 Mission cost (project evaluation etc.) | SDR | 18,050 |
| 1.4 Duty travel (literature survey and selection of equipment) | SDR | 10,830 |
| 1.5 Miscellaneous (communications etc.) | SDR | 10,830 |
| 1.6 Unpredictable | SDR | 21,660 |
| Total: | SDR | 606,500 |

2. Budget for Financing under the Second Account of the Common Fund (unit: SDR)

| | Total | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|---|
| Equipment | 530,680 | 288,810 | 216,600 | 25,270 | |
| Reagent, material | 14,450 | | | 7,230 | 7,220 |
| Mission cost | 18,050 | 10,830 | | | 7,220 |
| Duty travel | 10,830 | 3,610 | 7,220 | | |
| Miscellaneous | 10,830 | | 3,610 | 3,610 | 3,610 |
| Unpredictable | 21,660 | | 7,220 | 7,220 | 7,220 |
| Total | 606,500 | 303,250 | 234,650 | 43,330 | 25,270 |

ANNEX B3

Budget investment by China for development of rare earth doped cemented carbide

Total: SDR 129,964 (USD 180,000; basis 1 SDR = USD 1.385)

Budget unit: SDR

| | Total | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|---|
| Testing etc. | 25,270 | 6,500 | 6,410 | 6,300 | 6,060 |
| Contracts & service | 12,274 | 6,860 | 5,414 | ---- | ---- |
| Administration | 12,996 | 3,540 | 3,410 | 3,200 | 2,846 |
| Raw materials | 34,660 | 8,800 | 8,710 | 8,650 | 8,500 |
| Power & salary | 36,100 | 8,760 | 8,830 | 9,010 | 9,500 |
| Duty travel & survey | 8,664 | 2,500 | 2,050 | 1,390 | 2,724 |
| Total | 129,964 | 36,960 | 34,824 | 28,550 | 29,630 |

ANNEX-B4

Provisional Work plan
( 1993-1996)

| Content | 1993 | | | | 1994 | | | | 1995 | | | | 1996 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| 1. Addition of rear earth | | | | | | | | | | | | | | | | |
| 1.1 Proper kind of addition | ---- | ---- | | | | | | | | | | | | | | |
| 1.2 Addition method | | ------ | | | | | | | | | | | | | | |
| 1.3 Addition amount | | ------ | | | | | | | | | | | | | | |
| 2. Microstructure and wettability powder | | | ---- | ---- | ---- | ---- | | | | | | | | | | |
| 3 Pilot test, optimization of parameters | | | ---- | ---- | ---- | ---- | | | | | | | | | | |
| 4. Complete grade designing | | ---- | ---- | ---- | | | | | | | | | | | | |
| 4.1 Small batch production | | | | | ---- | ---- | ---- | ---- | | | | | | | | |
| 4.2 On-site test | | | | | | | | ---- | ---- | ---- | ---- | | | | | |
| 5. Perfection of process | | | | | | | | | | | | ---- | ---- | ---- | ---- | |
| 6. Promote application | | | | | | | | | | | | ---- | ---- | ---- | ---- | |

ANNEX-C1

A. Inputs by Common Fund

| | Description | Quantity | Source |
|---|---|---|---|
| 1. | Equipment | | |
| 1.1 | Vacuum sintering-quenching furnace | 1 | Common Fund |
| 1.2 | X-ray diffractometer | 1 | Common Fund |
| 1.3 | Atomic prob | 1 | Common Fund |

B. Inputs by China
See Annex 2 for project A,B and C.

ANNEX-C2

1. Financing under the Second Account of the Common Fund

1.1 Equipment

| | | |
|---|---|---|
| Vacuum sintering-quenching furnace | SDR | 72,200 |
| X-ray diffractometer | SDR | 324,920 |
| Atomic probe | SDR | 361,000 |
| Subtotal: | SDR | 758,120 |
| 1.2 Reagent, material (special material, spare parts of instrument) | SDR | 72,200 |
| 1.3 Mission cost (project formulation, monitoring and evaluation) | SDR | 36,100 |
| 1.4 Duty travel (literature survey and selection of equipment) | SDR | 28,880 |
| 1.5 Miscellaneous (communications etc.) | SDR | 21,660 |
| 1.6 Unpredictables | SDR | 43,300 |
| Total: | SDR | 960,290 |

2. Budget for Financing under Second Account (unit: SDR)

| | Total | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|---|
| Equipment | 758,120 | 454,870 | 267,150 | 36,100 | |
| Reagent, material | 72,200 | 28,880 | | 14,440 | 28,880 |
| Mission cost | 36,100 | 14,440 | 7,220 | | 14,440 |
| Duty travel | 28,880 | 14,440 | | 14,440 | |
| Miscellaneous | 21,660 | 7,220 | 3,610 | 3,610 | 7,220 |
| Unpredictable | 43,330 | | 7,230 | 18,050 | 18,050 |
| Total | 960,290 | 519,850 | 285,210 | 86,640 | 68,590 |

ANNEX C3

Budget for investment by China for development of heat-treated cemented carbide

**Total: SDR 194,946** (USD 270,000; basis 1 SDR = USD 1.385)

Budget Unit: SDR

| | Total | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|---|
| Testing etc. | 46,931 | 12,700 | 12,200 | 11,560 | 10,471 |
| Contracts & service | 17,329 | - - | 6,020 | 5,700 | 5,609 |
| Administration | 11,552 | 2,900 | 2,950 | 2,882 | 2,820 |
| Raw materials | 46,210 | 13,270 | 12,080 | 11,550 | 9,310 |
| Power & salary | 63,538 | 15,750 | 15,820 | 15,884 | 16,084 |
| Duty travel & survey | 9,386 | 2,400 | 2,030 | 2,160 | 2,796 |
| Total | 194,946 | 47,020 | 51,100 | 49,736 | 47,090 |

ANNEX C4

Provisional Work plan

| | Content | 1993 | | | | | | | | | | | | 1994 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1. | WC-Co systems | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.1 | Optimization of process parameters | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.1.1 | Quenching and tempering | | | | | | | - | - | - | - | - | - | | | | | | | | | | | | |
| 1.1.2 | Selection of quenching methods | - | - | - | - | - | - | - | - | - | - | | | | | | | | | | | | | | |
| 1.1.3 | Minimum speed for strengthening and toughening | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| 1.2 | Research on microstructure of heat-treated alloys | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1.3 | On-site test | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| 2. | WC-TiC-(TaC-NbC)-Co | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.1 | Research on heat-treatment processes | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - |